Study on the Development Mode of Urban Underground Logistics System

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Abstract

It is an effective means for developing urban underground logistics system to solve the bottleneck of the urban space development. Based on the research experience of underground logistics system both at home and abroad, the urban underground logistics system development models were proposed and analyzed comparatively including their characters, research status, application scope and technical parameters. The analysis showed that on the one hand different development modes of the underground logistics had great influence on its building and application scope, on the other hand it had has reference value to urban underground logistics development and research.

Keywords

Urban Underground Logistics System; Development Model; Technical Parameter

Introduction

Urban underground logistics system is regarded as an effective way to solve these problems in order to alleviate the increasingly serious problem of urban freight transport, ease the contradiction conflict among urban logistics and urban transport, urban society, space resources and environment in the development process, promote sustainable development of urban logistics, conform to the new trend in the development of e-commerce logistics. At present, urban underground logistics systems generally have the following characteristics in the various countries.

1) Urban Structure and Land use Aspects

It inclues reducing the land occupation including road freight station, parking and other facilities.

2) Freight Efficiency

It inclues reducing urban freight costs and improving freight services; avoiding the road congestion during the storm, rain, snow and other inclement weather disasters conditions and providing higher level of service which is much more reliable, punctual and safey than the existing truck-based urban freight system; conforming to e-commerce development and requirements in the future;

3) Road Traffic Safety

It inclues reducing traffic accidents caused by urban freight transport;

4) Urban Social Environment

It inclues reducing energy consumption, such as freight vehicles emissions, traffic noise and vibration caused by a variety of freight vehicles.

These characteristics had also become necessary elements to develop the underground logistics system. In various countries, underground logistics system researchers comply these design requirements, put forward different types of underground logistics system development model, and make the conceptual design the related technical facilities and equipments.

Development Model of Underground Logistics System

Through integrating the designs and studies about underground logistics system conceptual models by scholars at home and abroad, underground logistics system development model could be summarized as the three underground logistics system development model: based on the metro model, pipeline cabin model and vehicle model.

Underground Logistics System Development Model Based on Metro

Based on metro underground logistics system was that relying on the perfect urban metro system the freight was divided into the metro compartment where the passenger and freight were in the same column. At

last, the freight was sent to the customer with the ground transport. Related research included that BA Pielage, JC Rijsenbrij (2002) proposed the concept that the metro was used for urban freight and analyzed the cargo capacity of the metro. Zhang Min, Yang Chao, Yang Jun (2005) analyzed logistics system underground construction experience in the various countries and proposed that underground logistics system should be built closely combined with metro construction and the metro system achieved "a dual-use". Liu Yubo, He Ketai, Liu Jie, etc. (2008) analyzed the feasibility and issues of urban freight by the metro and proposed the concept of urban logistics based on the metro. He Ketai, Shao Juping, Liu Yubo, etc. (2008) proposed the Metro-style underground logistics system concept, cost calculation model and line selection strategy, and analyzed the transport processes, transport units, logistics management and control and logistics cost.

Conceptual Model of the Cabin-Style Underground Logistics System

Conceptual model of the cabin-style underground logistics system was a modern form of underground logistics based on the capsule pipeline technology which was round or square wheeled transport capsule. Transport capsule only had basic load function, did not have drive, oriented function, steering and other functions. Its steering function was passive completed through tracks or pipe wall. At its corner, the wear rate of facilities and equipment was higher. Pipeline construction structure and wall material properties had higher requirements. Qian Qihu, Guo Dongjun (2007) proposed that the cabin-style underground logistics system was divided into three categories: pneumatic cabin pipeline transport, hydraulic cabin pipeline transport and electromagnetic cabin pipeline transportation. Pneumatic cabin pipeline transport and hydraulic cabin pipeline transport were used for mail, parcels, vegetables, fruits and other fast transportation materials. Hydraulic cabin pipeline transport was used for earth and sand, ore and other large capacity, long-distance transport materials. Cabin conceptual model of underground logistics system was joined through multi-faceted wheels and the pipe wall. The number of its contact surfaces was more than three in general. The friction of its operation was too large that the depletion of the piping, cabin and other equipment was severe, so some scholars used orbit to reduce running resistance. Herry Liu and Dietrich Stein designed a conceptual model of gravity orbital module body and the United States NJIT's body hanging orbital conceptual model.

The research on cabin-style underground logistics system conceptual model was relatively broad and in-depth focused on vehicle design and piping design. Montgomery, Bruce Fairfax, Stephen; Smith, Bradford (2001) established the electromagnetic cabin pipeline experimental model and analyzed the actual operating parameters. Robert M. O'Connell, PE, Charles W. Lenau, PE, Tuo Zhao (2010) analyzed the applications of linear induction motor in PCP and simulated the operation of the cabin. Kosugi, Sanai (1999) designed the cabin structure, simulated and analyzed of the cabin operating characteristics. Sanai Kosugi (2001) analyzed the experiences and applications and future trends PCP in Japan. Obiajulu N. Egbunike, Andrew T analyzed the cabin pipeline transport in the UK and Europe, the application and development experience, the advantages and disadvantages of cabin pipeline transportation in detail. Henry Liu (2004) studied the feasibility of underground pneumatic freight in the New York, constructed pneumatic cabin based on the underground transport logistics system, designed the conceptual model of the tunnel structure, container units, carrying tools, etc. and made specific analysis and reasoning about conceptual model elaborated PCP of linear electric motors, cabin, facilities construction and investment costs and application. Henry Liu and Charles W. Lenau (2005) studied the transport of ore and waste pipeline transportation electromagnetic drive cabin, designed the track, tunnels, cabin and facilities conceptual model and analyzed the operation of the system, the state and capital costs.

1) Pallet-Tube-Style PCP System Designed by Herry Liu

TABLE 1 TRAY - PIPELINE VEHICLE SPECIFICATIONS

Parameters		Parameters	
Vehicle length	13ft	Vehicle height	4ft
Vehicle width	4ft	maximum effective laden	4.16 ton
Transport capacity	4ft × 4ft × 13ft	drive	wind power or electromagnetic induction

Herry Liu (2004) designed the Pallet-Tube-style PCP system that was mainly used to distributed containerized cargoes in New York City (including pallets, cartons, boxes and cargo bags, etc.). The pipelines carrying tools cabin was used for transport vehicle without the drive, steering, guidance and other functions, only with a carrying

function, and its technical parameters are shown in Table 1.

2) *Cabin Logistics System Designed by Ma Baosong*

Ma Baosong (2005) designed primarily cabin logistics system for urban distribution. The cabin pipeline transportation was used as the conveyance. There was much different for the tray- pipeline conveyance designed by Herry Liu in the U.S. including its cargo tools such as driven oriented features. Its cabin had no clear specific technical indicators, whose cross-section was circular radius [1.5 m, 2.5 m], 10-wheel drive.

Vehicle Conceptual Model of Underground Logistics System

Vehicle concept model of underground logistics system used a special vehicle to complete underground freight, generally used a battery as the energy to drive, such as AGV in the Netherlands and DMT in the Japan.

The indicators of smoothness and tightness of the pipeline carrying tools, wall materials needed lower requirement, with only basic functions can tunnel, but without lighting, maintenance, relieve fatigue driving and other supporting functions. Dietrich Stein (2004) designed CargoCap vehicle-style underground logistics system conceptual model, proposed for the set with tray unit installed underground logistics system for the LAN terminal conceptual model of planning and design of future trends. Jan Scholten, Peter Knuepfer, Martin Schmitt (2005) conducted a CargoCap-underground logistics system in conceptual model experiments, simulated and analyzed CargoCap underground logistics system concerning conceptual model of operating parameters. Yang Tao, Yang Dongyuan, He Yongzhan(2002) introduced the Japanese network structure, two car DMT and system efficiency calculation model .

1) *Underground Logistics CargoCap System Designed by Dietrich Stein*

Dietrich Stein (2004) designed underground logistics CargoCap system mainly used for Essen (Essen), Bochum (Bochum), Bremen (Bremen) inter-regional freight and other cities to provide underground logistics services. CargoCap Vehicle concept model had track technology, automated handling technology and automatic navigation technology. Vehicle technical parameters are shown in Table2.

TABLE 2 CARGOCAP CONCEPTUAL MODEL OF THE TECHNICAL PARAMETERS [21]

Parameters		Parameters	
Maximum payload	1500kg	Track width	800mm
Maximum speed	39.6km / h	Average speed	36 km / h
Maximum acceleration	1 m/s2	Wheel diameter	200mm
Vehicle width	1400mm	Vehicle height	1600mm
Vehicle length	4000mm	Max.gradeability	3%
Transport capacity	2400mm × 800mm × 1050mm		

2) *Underground Logistics System Designed by Ben-Jaap Pielage*

Ben-Jaap Pielage(2001)designed underground logistics system mainly for Hoofddorp train station, Schiphol Airport and the Aalsmeer flower auction market between freight. AGV was used as carriage tool of underground logistics system in the Netherlands, whose model had three styles, as shown in Table 3. Its associated properties are shown in Table 4.

TABLE 3 THREE STYLES OF UNDERGROUND LOGISTICS SYSTEM IN THE NETHERLANDS

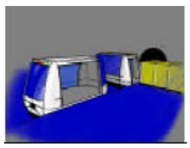
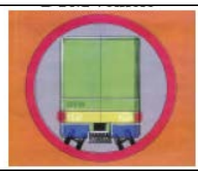
Spykstaal	Lödige	DTM
		
AGV	AGV rail can be installed in the terminal rubber wheels with AGV	AGV
Front-wheel drive	four-wheel drive	front-wheel drive
Wheel located under the loading plate loading	plate is located between the wheel mounting plate	located between the wheels
Front and side loading	side loading	side loading
Using the battery as a power battery is used as power terminals	the track rails powered by the runtime	he track rails powered by the runtime. Using battery as a power

TABLE 4 THE NETHERLANDS VEHICLE SPECIFICATIONS

Parameters		Parameters	
Average speed	6~10m/s	minimum speed	3m/s
Max.gradeability	12%	maximum acceleration	1m/s^2
Maximum negative acceleration	2 m/s^2	terminal velocity	2m/s

Three Conceptual Design Parameters Related Technologies

Currently, underground logistics system concept design includes vehicles, pipes and assembled unit.

The following brief passage design and assembled cell design.

1) Channel Diameter Conceptual Design Parameters

Qian Qihu, Guo Dongjun (2007)proposed that underground logistics system should be divided into pipes channel form and tunnel form. With the underground trenchless technology application and development, particularly in pipe jacking technology widely used, the current size of the pipe could be built up DN/ID 4100 or DN / OD 5000. It was difficult to judge tunnel pipeline transportation or freight channels from the external structure. But the forms of transport are different. Therefore, the distinction between these two modes of transport did not limit its external structure, but only in carrying on its own characteristics. Pipeline transportation vehicle had only carrying cargo capacity, did not have the drive, braking, guidance and other functions, to rely on external support facilities equipped and had a guide pipe, bearing, supporting other effects, its architecture and materials sealing, smoothness and other demanding. Tunnel pipeline transport had only a supporting role, whose structure was relatively simple, and its means of transportation itself had driven orientation, braking and other functions. Futurist abroad began to consider applications for long-distance freight tunnel system. These concepts were largely used based on large-diameter tunnel (diameter of about 5m) and higher transport speed (at 300 - 500 km/h). Currently, countries in building research channel dimensions are shown in Table 5.

2) Conceptual Design Parameters of Assembled Unit

At present, study on underground logistics system mostly treats assembled pallets and containers as a unit, such as Henry Liu, etc. (2004,2005), Dietrich Stein, etc. (2005), Ben-Jaap Pielage, etc. (2005) designed assembled unit parameters as shown in Table 5. Previously a conceptual model of the underground logistics system was introduced as a set of multi-use pallet loading unit, now there are many scholars in the underground logistics system using a container assembled unit. Dietrich Stein, Robert Stein, Dietmar Beckmann, etc. (2005) designed container as assembled units CargoCap-underground logistics system concept model, which was dedicated platform for a detailed design. BERT VERNIMMEN designed underground container port logistics system and analyzed building conditions and freight demand. Container operations process required high level. Container disassembly, handling, transportation and other logistics processes required large-scale logistics facilities to help complete reference to the third generation in Europe, America and other countries port design, and the width of its container operations was generally 40~45m combined with a huge container operations vehicles (e.g X6A type container special vehicles, length 13000 mm, width 3070 mm). These occupied a very impressive road area, resulting in land size of underground logistics terminal in the tray as far beyond the container terminal logistics unit of the underground. In addition, trays and containers of different sizes between underground logistics system directly affect the conceptual design, system design, such as Germany CargoCap ULS two modes, one of which is the European standard pallet: Assembled unit of underground city freight system; while the other is the container for the assembled unit area underground freight system, size, and related conceptual design shown in Table 6.

TABLE 5 WORLD CARGO PIPE DIAMETER SUMMARY TABLES

Transportation	Project Name	Location	Pipe diameter	Construction Time
Pipeline Transportation	London Pneumatic Despatch System	London	30×33in	1863~1869
	Hamburg postal system	Hamburg, Germany	450mm	1962
	Pipeline Express（Tubexpress）	USA and Georgia State	910	1971
		Houston, United States	450	1973
	Transprogress	Russia	1220	1971~1983
	Subtrains	New York	1050	
	Sumitomo system	Japan	1000	1983
	Japan LSM cabin systems	Kawasaki	300	1994
	Demonstration Project	Florida	610	2000
Tunnel Rail transport	London Postal (subway freight) system	London	2740	1927
	Automated network of underground tunnels	Tokyo, Japan	5500	
	ULS	Netherlands	1150~5000	
	CargoCap system	Bochum	1600	1998-

TABLE 6 UNDERGROUND LOGISTICS MAJOR CONTAINER UNIT DIMENSIONS

Country / Region	principal investigator	investigator assembled unit type	size
American	Henry Liu etc.	containers	40ft、20ft
Germany	Dietrich Stein etc.	containers	45ft
American	Henry Liu etc.	Pallet	1219 mm×1016 mm
Germany	Dietrich Stein etc.	Pallet	1200 mm×800 mm
Netherlands	Ben-Jaap Pielage etc.	Pallet	3180 mm×2440 mm

TABLE 7 DIFFERENT CARGOCAP SYSTEMS ASSEMBLED UNIT PARAMETERS

Assembled unit	pallet	container
Container Unit dimensions	1200 mm×800 mm	12192 mm×2438 mm×2896 mm
Capitally	2400 mm×800 mm×1050 mm	11998 mm×2330 mm×2566 mm
Single	1.6 m(Round)	5.31 m×6.99 m (square)
Channel Minimum turning radius	20 m	1000 m
Channel maximum gradient	4%	1.25%

Conclusions

Metro-style underground logistics system of conceptual model was the open embedded systems, relying on metro network to complete its transit. Its operation was affected and restricted by passenger operation. Currently, the model study is not perfect, and its limitation is numerous. Especially its logistics concepts are contrary with some of today's concepts. Cabin-style underground logistics system in conceptual model needed drive or outside driving force to run. During its running segment, the vehicle occupied the entire channel so that the delivery was not continuous. It was difficult to adapt to low-volume, multi-batch distribution for the urban distribution. In addition the reachability of pipeline was so poor that short split was needed to complete the final ground distribution. By contrast, the conceptual model of the vehicle-style underground logistics system was better to adapt to urban distribution characteristics. Currently, Japan, the Netherlands, Germany, are the most representative about the model researches on underground logistics system conceptual model, whose research focus on vehicle design, other design parameters missing each other. With the research of underground logistics system at home or aboard, the different development patterns, construction requirements and scopes of under underground logistics system had great differences. In this paper, underground logistics system development model was divided into three types, and related technical characteristics were summaruzed and comparatively analyzed in order to provide some useful experience and ideas for building urban underground logistics system.

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